Revision of the Background Error Covariance in the Global 3D-Var Data Assimilation System

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A 3D-Var data assimilation system was implemented in the operational global analysis at JMA in September 2001 (Takeuchi and Tsuyuki, 2002). Although the 3D-Var system has brought much improvement on the operational numerical weather prediction at JMA, there have been a problem that the background error correlation was too strong at large scales, so that each observational datum affected undesirably wide range of the field in data assimilation. It was recently found that the cause of the problem was an artificial smoothing operated on the vorticity background error covariance. The smoothing was originally introduced in order to suppress the horizontal correlation of the control variables at large distances. The smoothing, however, was found to have a side effect of excessive correlation in the vorticity-balanced part of the increment at low frequencies.

Figure 1 displays the increment in surface pressure dP_S when a single P_S observational datum is assimilated. With the artificial smoothing operated on the background error covariance, the increment is spread over wide range. Without the smoothing, it is reasonably localized around the datum point. Figure 2 displays the power spectrum of the increment of modified balanced mass variable df_B, which accounts for much of the increment dP_S, and which directly reflects the properties of the background error covariance of the vorticity field at low frequencies. It can be seen from the figure that the amplitudes of the increment df_B at low frequencies are unnatural when the smoothing is operated.

Figure 3 displays the time-series of the analyzed temperature at 300 hPa, averaged over the antarctic region. The time-series are obtained by cycled analyses performed under several different conditions. The result obtained from the global analysis by UK Met Office (UKMO) is also shown for reference. The temperature suddenly rises at 12 UTC September 25, 2001, when the assimilation method changed from OI to 3D-Var with the artificial smoothing on the background error covariance ("OI→3DVAR" line). In order to moderate the sudden change of the temperature, a modification was applied in the operational process at JMA on the regression coefficient between the background error of modified balanced mass variable and that of unbalanced temperature ("RTN" line). In this case, the temperature is almost steady but systematically higher than that obtained by OI. Drastic changes in the temperature can be averted without applying any modification on the regression coefficient, if 3D-Var was performed without the artificial smoothing on the background error covariance ("without smoothing" line).

Following the investigation described above, the artificial smoothing on the

background error covariance and the modification on the regression coefficient were stopped in the operational 3D-Var system at JMA in May 2003.

References

Takeuchi, Y. and Tsuyuki, T., 2002: The operational 3D-Var assimilation system of JMA for the Global Spectrum Model and the Typhoon Model. In: *Research Activities in Atmospheric and Oceanic Modelling*, H. Ritchie (Ed.), Volume No. 32, WMO/TD-No. 1105, pp. 1.59 – 1.60. WMO.
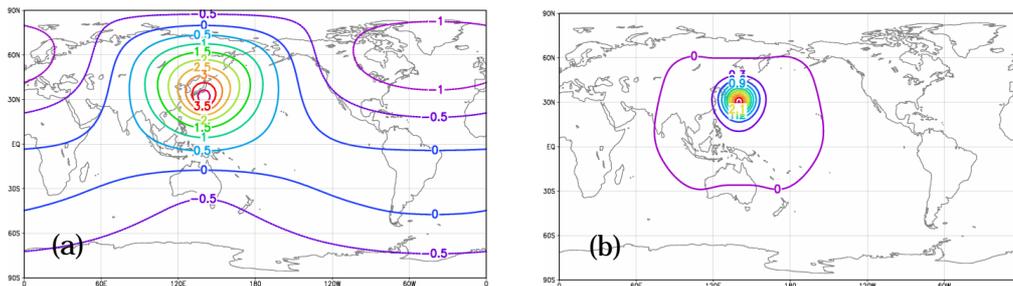
Fig. 1 Increment in P_S when a single P_S observational datum is assimilated.

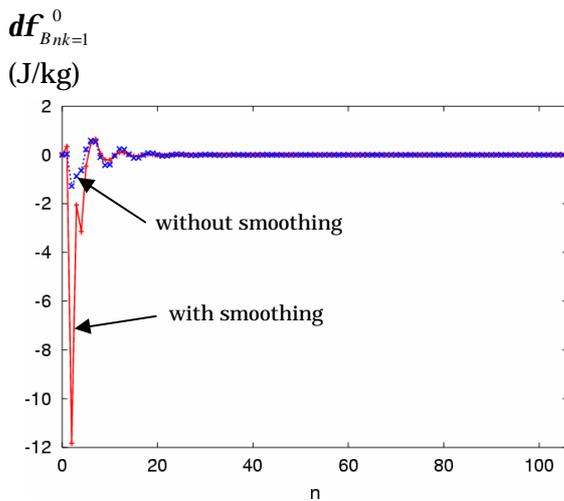The datum is put at the point (30N,140E). (a): with smoothing, (b): without smoothing.

Fig. 2 Power spectrum of $\boldsymbol{df}_B$.

The result is displayed for the lowest model level, and for zonal wavenumber $m = 0$.

(n : total wave number)
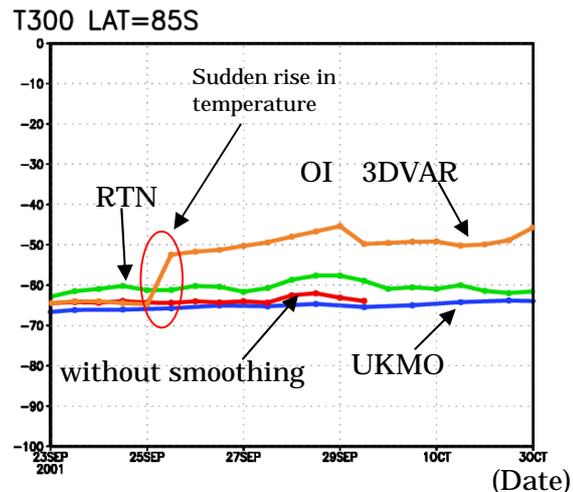
Fig. 3 Time-series of analyzed antarctic temperature in centigrade at 300 hPa, averaged over the circle of latitude 85S.

i) OI　3DVAR: Analysis method changed from OI to 3D-Var at 12UTC Sep. 25, 2001. The 3D-Var is performed with the artificial smoothing on the background error covariance.

ii) RTN: 3D-Var implemented in the operation at JMA. With the smoothing on the background error covariance. Modification on the regression coefficient is applied.

iii) UKMO: Global analysis by UKMO.

iv) without smoothing: 3D-Var without the smoothing on the background error covariance. The modification on the regression coefficient is not applied.